DOCUMENT RESUME

ED 252 432 SE 045 354

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TITLE Rotating Biological Contactors (RBC's). Student Manual. Biological Treatment Process Control.
INSTITUTION Linn-Benton Community Coll., Albany, Oreg.
SPONS AGENCY Environmental Protection Agency, Washington, DC. Office of Drinking Water.
PUB DATE 84
GRANT EPA-T901238
NOTE 49p.; For related documents, see SE 045 333-353.
AVAILABLE FROM Linn-Benton Community College, 6500 S.W. Pacific Blvd., Albany, OR 97321.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Biology; Laboratory Procedures; Post Secondary Education; *Sludge; *Training Methods; *Waste Disposal; *Waste Water; *Water Treatment
IDENTIFIERS *Rotating Biological Contactors; Unit Processes

ABSTRACT

This student manual provides the textual material for a unit on rotating biological contactors (RBC's). Topic areas considered include: (1) flow patterns of water through RBC installations; (2) basic concepts (shaft and stage); (3) characteristics of biomass; (4) mechanical features (bearings, mechanical drive systems, and air drive systems); (5) design considerations (flow rates, organic and solid loads, industrial loading, and weather/environmental influences); (6) interaction of unit processes (preliminary treatment, primary clarifier, return stream and secondary clarifier); (7) process monitoring and testing, focusing on the visual observation of the biomass; (8) process control for steady state operation (considering mechanical and air drive systems); and (9) making process control changes. A list of objectives, a glossary of key terms, a list of references, and student worksheets are included. It is assumed that students using this manual have had some experience in wastewater treatment and a basic understanding of biological treatment. (JN)

Biological Treatment Process Control

Rotating Biological Contactors (RBC's)

Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL TREATMENT PROCESS CONTROL

ROTATING BIOLOGICAL CONTACTORS (RBCs)

STUDENT MANUAL

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Developed Under:
EPA Grant #T901238
1984

ROTATING BIOLOGICAL CONTACTORS
(RBC's)

Table of Contents

ROTATING BIOLOGICAL CONTACTORS
(RBC's)

Objectives

Upon completion of this lesson you should be able to do the following:

1-Describe or define a Rotating Biological Contactor as it is used in different flow schemes or applications for the treatment of wastes.

2-Identify the RBC process as a secondary biological treatment process.

3-Identify the RBC components.

4-Define the terms shaft, stage, and train as applied to RBC's.

5-Identify the two different types of drive systems and the advantages and disadvantages of both.

6-Describe the characteristics of the biomass growth of the RBC treatment system through the different stages by visual observation.

7-Suggest a list of process control laboratory tests that can be applied to an RBC system.

8-Be able to calculate the hydraulic loading on an RBC system and compare that to a normal design range.

9-Be able to calculate the organic loading on an RBC system and compare that to a normal design range.

10-Describe the changes that should be made in a RBC system to obtain maximum BOD removal and/or adjust for high organic loadings.

11-Describe the changes that should be made to encourage nitrification in an RBC system.

ROTATING BIOLOGICAL CONTACTORS
(RBC's)

Glossary

air drive system - a method of rotating an RBC shaft through the process water. This system consists of a compressed air source and air header that bubbles air through the process water. This process air is caught in air "cups" attached to the sides of the drum which rotates it.

disc - synthetic media that is turned through the process water and provides a surface for the biomass to grow. Multiple discs will make up one shaft.

mechanical drive system - a method of rotating an RBC shaft through the process water. This system consists of a drive motor and gear reducer.

nitrification - the aerobic biological conversion of ammonium nitrogen to nitrate-nitrogen. The bacteria involved are usually referred to as nitrifying bacteria.

RBC biomass - attached biological growth from the RBC process that is usually only aerobic in content. This biomass growing on the media is generally no more than a few hundredths of an inch thick.

RBC or Rotating Biological Contactors - the wastewater treatment process in which a shaft containing synthetic media is rotated in a tank filled with process water.

shaft - the rotating "drum" of the RBC unit that is defined as being from bearing to bearing and includes the media. Shafts are usually 12 feet in diameter and up to 25 feet long.

sloughing - the action of the biomass becoming detached from the media. This can occur naturally as the biomass grows in thickness and weight or this may occur due to toxic loads or severe temperature change. These biomass solids are settled from the process stream in the clarifier.

stage - an individual hydraulic section or part of an RBC system. A stage is the hydraulic point of no return. It can be a tank or a distinct basin.

train - a series of RBC stages which take the flow from the influent to the effluent. There can be more than one train in a given plant.

zoogleal slime - the biological growth from the trickling filter process that consists of both aerobic and anaerobic organisms.

ROTATING BIOLOGICAL CONTACTORS
(RBC's)

CONCEPTS AND COMPONENTS

INTRODUCTION

Rotating biological contactor has been generally accepted as a standardized name to describe the wastewater treatment process in which a shaft containing synthetic media is rotated in a tank filled with process water. It is physically a different concept than either a trickling filter where the media is stationary and the process water flows through by gravity or activated sludge where the organisms are in suspension in a tank.

The biological growth in an RBC secondary treatment process more closely resembles the zoogleal slime from a trickling filter than the mixed liquor from an activated sludge process, but there is one major difference. While the trickling filter growth is layered with aerobic organisms living in the outer layers and anaerobic organisms living next to the media, the RBC growth is intentionally kept thin to discourage anaerobic organisms. A distinction is made in terminology by referring to the RBC growth as biomass.

RBC's are most commonly used as a secondary treatment process, but are also used in advanced wastewater treatment processes. When temperatures are high enough and carbonaceous BOD is low enough, a shaft of media identical to that used in secondary treatment will develop a biomass consisting of primarily nitrifying bacteria which will convert remaining ammonium-nitrogen to nitrate-nitrogen. If denitrification is required following nitrification, totally submerged RBC shafts in anoxic tanks are used to grow a denitrifying bacteria population. The denitrifiers convert the nitrate to nitrogen gas which bubbles to the surface and escapes to the atmosphere.

FLOW PATTERNS

General Flow Path

The flow pattern for the water through an RBC installation is much the same as for any other biological system. Pretreatment to remove grit and screenings is desired to prevent buildup under and on the rotating discs. Primary clarifiers for sludge removal reduces the solid load that could cause problems both in and under the discs.

A secondary clarifier must be provided for sludge removal and provisions for disinfection following the secondary clarifier if required by the local regulatory agency. Figure 1 shows this flow pattern.

Solids handling may be accomplished several ways. No manufacturer presently advocates recycle of sludge from the secondary clarifier to the RBC like the return sludge route in the activiated sludge. Some designers choose to pump secondary sludge back to the primary clarifier for resettling with the primary sludge. Others direct secondary solids and primary sludge separately to the solids stabilization and handling step. See Figure 2.

Some plants have been designed with no primary clarifier, however this is considered poor practice due to solids buildup in the RBC basin.

Series and Parallel Flow

There are two basic arrangements for liquid travel through more than one RBC and two ways to arrange flow into the RBC basin. More detail is presented later in the lesson why different arrangements were used. Generally series flow is used to reduce the load to minimum and to permit nitrification in later stages. Figure 3 illustrates both parallel and series flow. Parallel flow is used to distribute high organic waste flows over several first stage units to absorb shock loads.

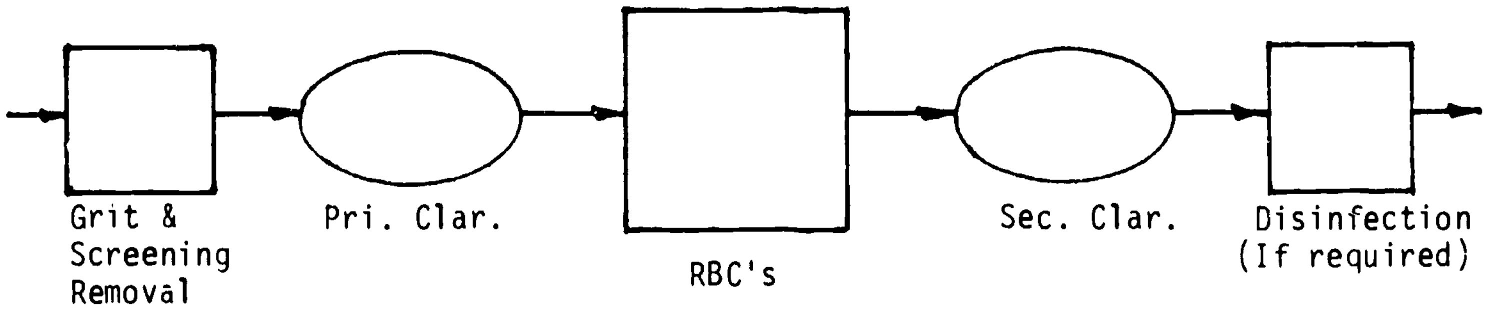


FIGURE 1

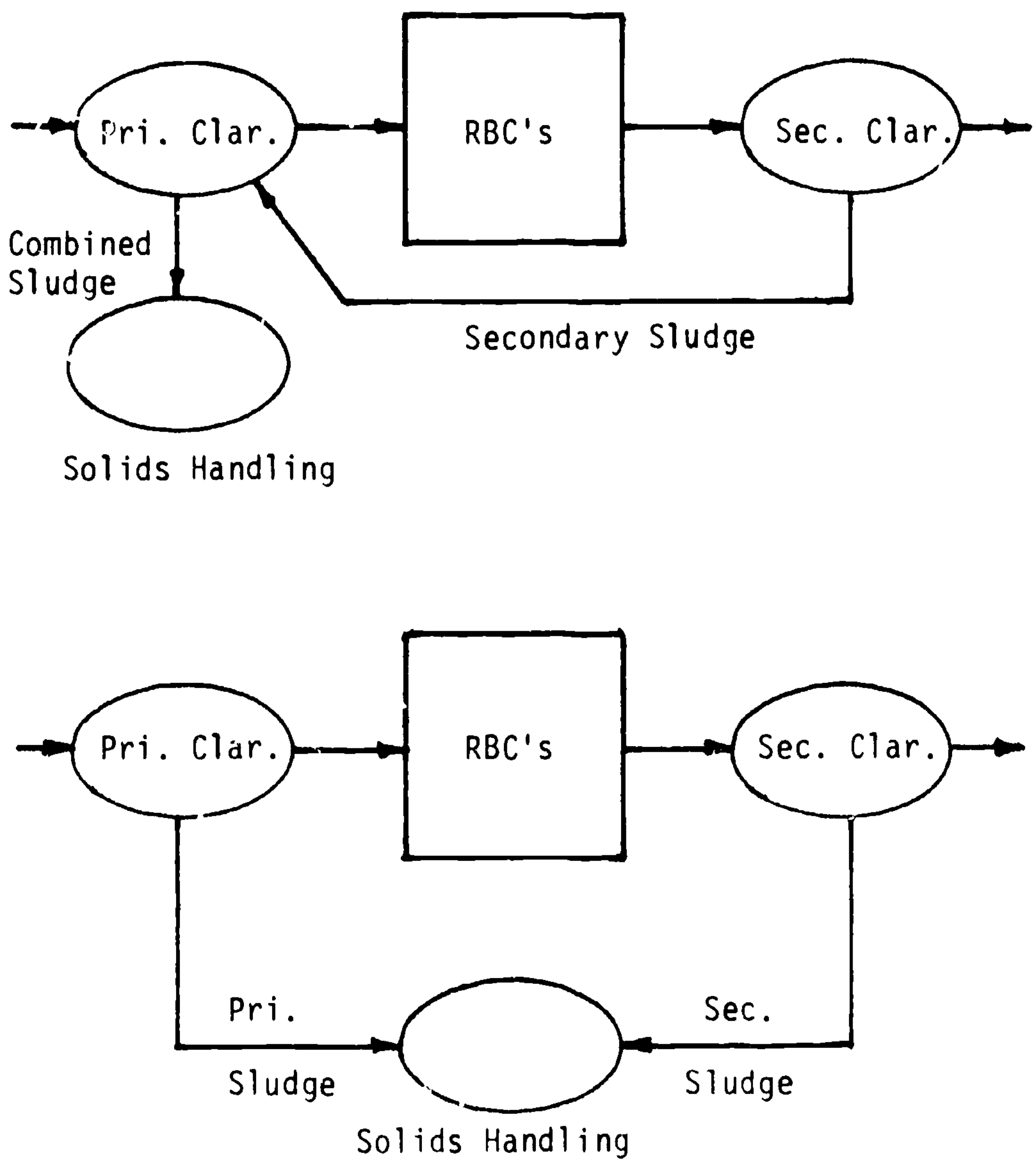
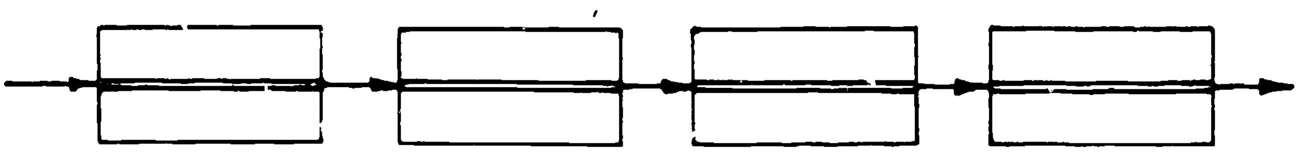
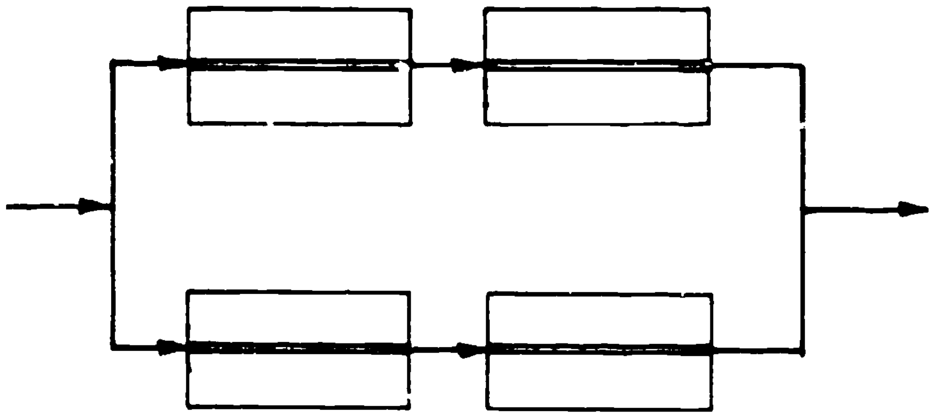


FIGURE 2

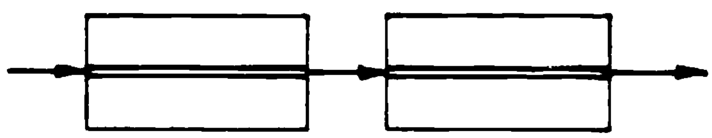


SERIES FLOW

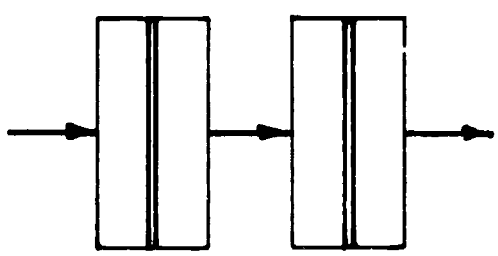


PARALLEL FLOW

FIGURE 3



FLOW PARALLEL TO SHAFT



FLOW PERPENDICULAR TO SHAFT

FIGURE 4

Flow may enter the basin either parallel or perpendicular to the shaft. See Figure 4. When parallel flow is used the shaft may develop higher growth at the inlet end compared to the outlet. Flow introduced perpendicular to the shaft will be spread over the entire disc surface evenly. The next section of this lesson describes how the parallel pattern may be used to provide two stages with one shaft.

BASIC CONCEPTS

In order to talk in the same language, there are two terms we need to define and explain -- shaft and stage. The shaft is the rotating part. It goes from bearing to bearing and includes the media. See Figure 5. Shafts are usually 12 feet in diameter and up to 25 feet long.

A stage is the hydraulic point of no return. It can be a tank or a distinct basin. See Figure 6. The water contained between the inlet and outlet within a stage can be considered to be well mixed.

A train consists of a series of stages which take the flow from influent to effluent. Figure 7 shows one train of three stages. Parallel systems have more than one train. Figure 8 shows two parallel four stage trains.

You can have two stages on one shaft by using baffles. See Figure 9. Once the water leaves the first stage, it does not go back.

You can have two shafts in one stage. See Figure 10. The water within the stage is completely mixed.

You can make two stages into one stage by taking the baffle out. See Figure 11. There is now only one tank and the water is free to mix completely.

You can make one stage into two stages by putting a baffle in. See Figure 12. The water is no longer free to mix, therefore, two stages.

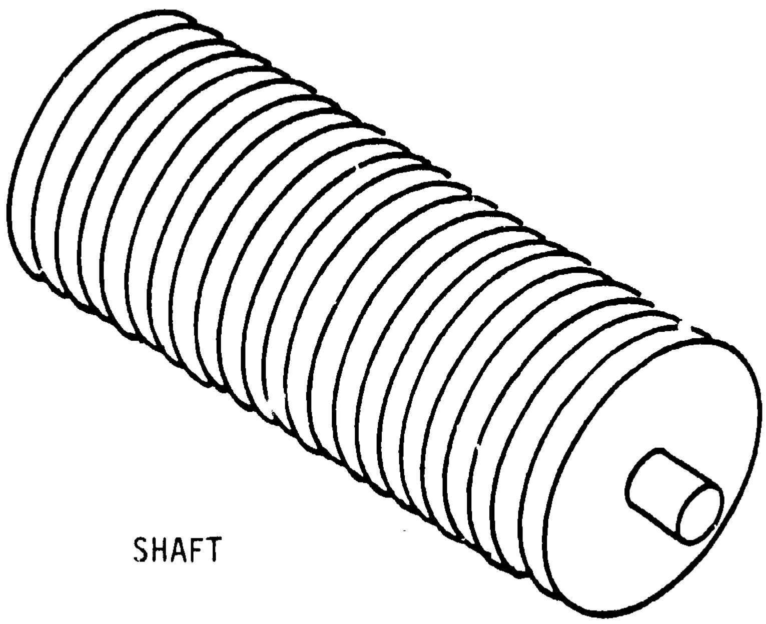


FIGURE 5

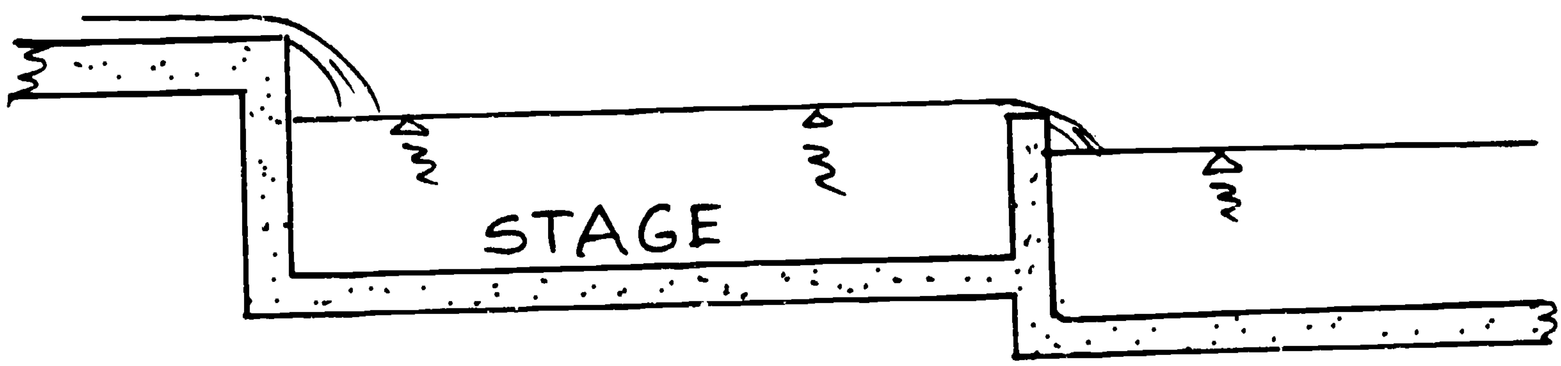
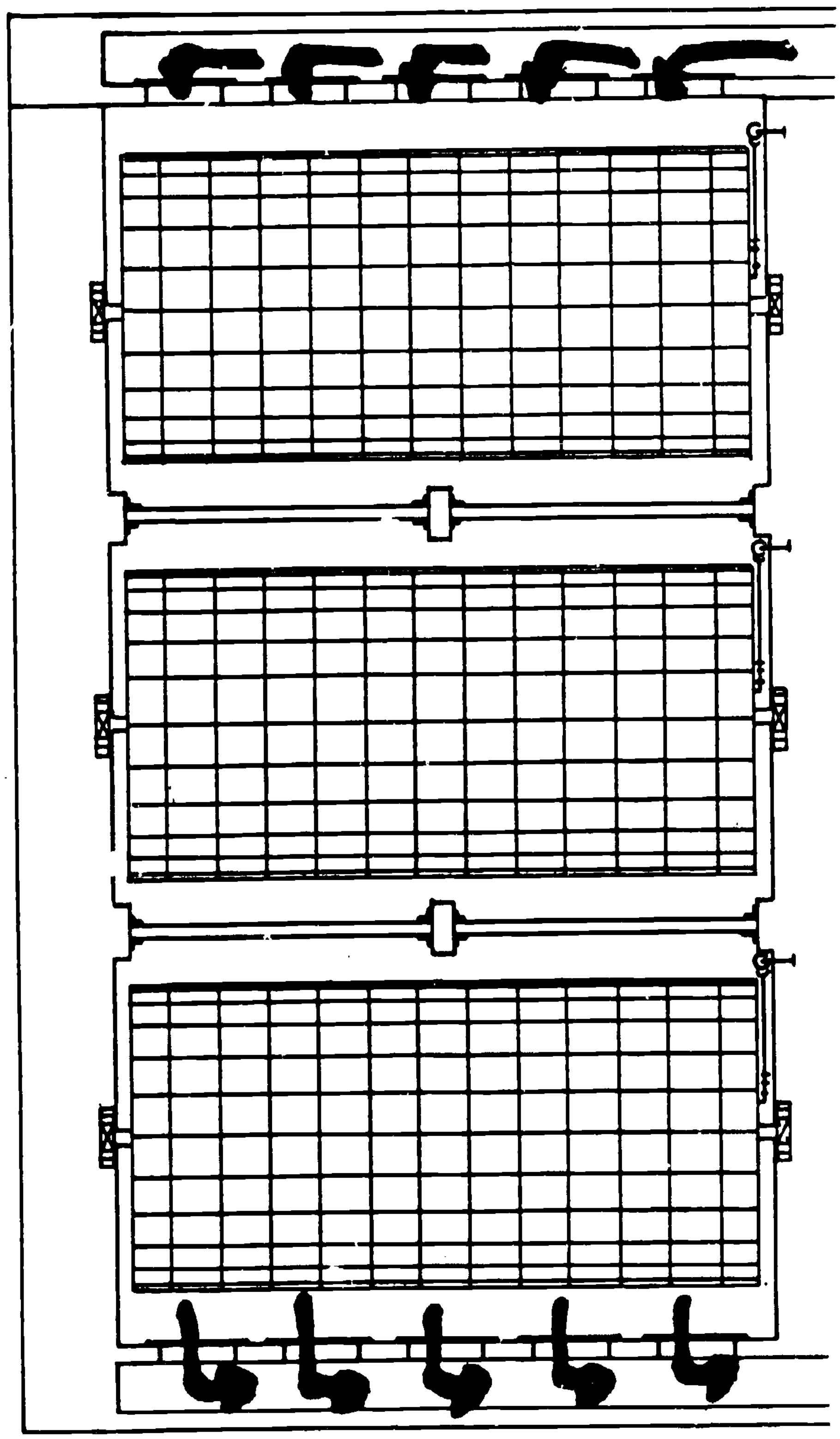
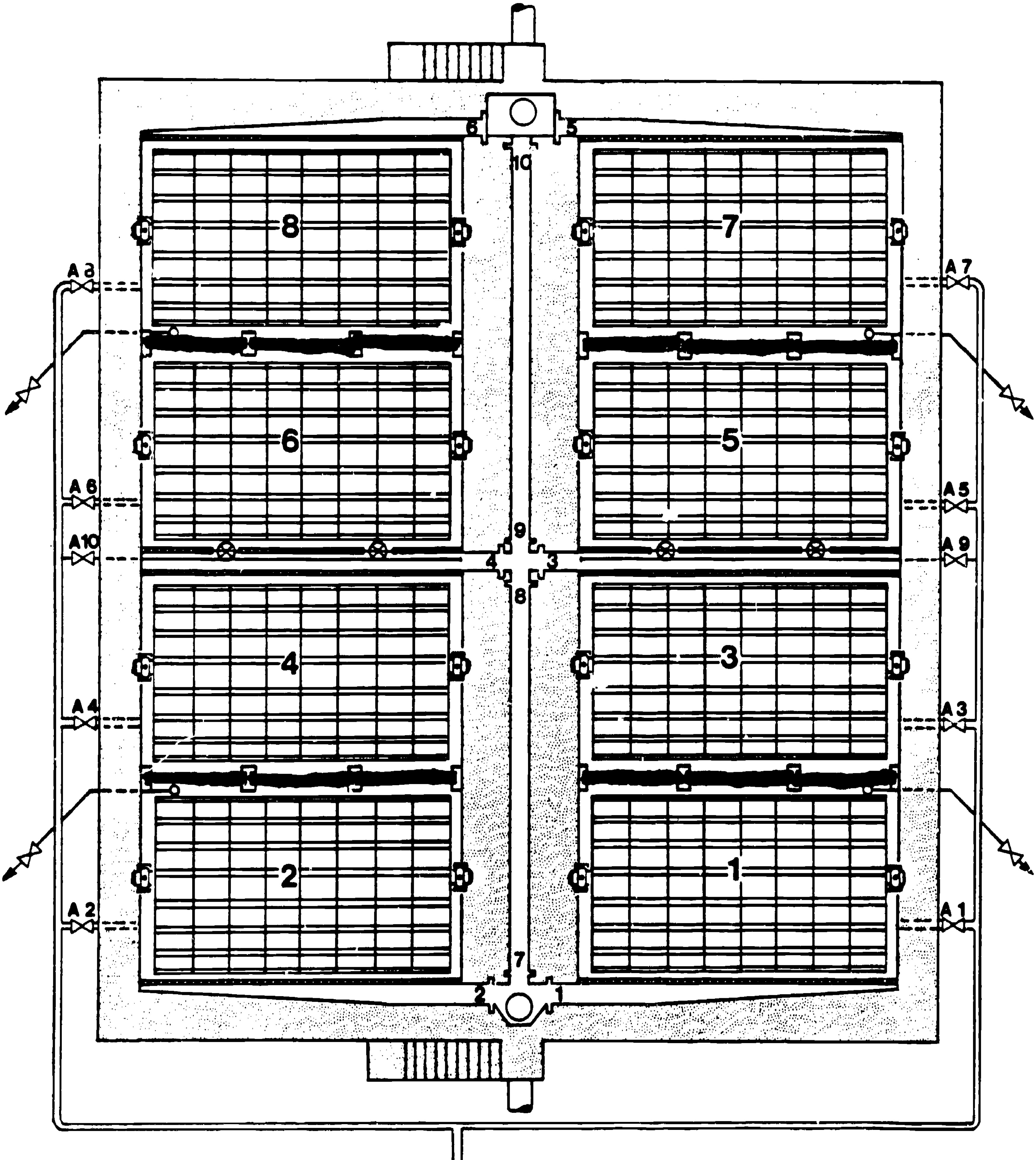


FIGURE 6



ONE TRAIN OF THREE STAGES

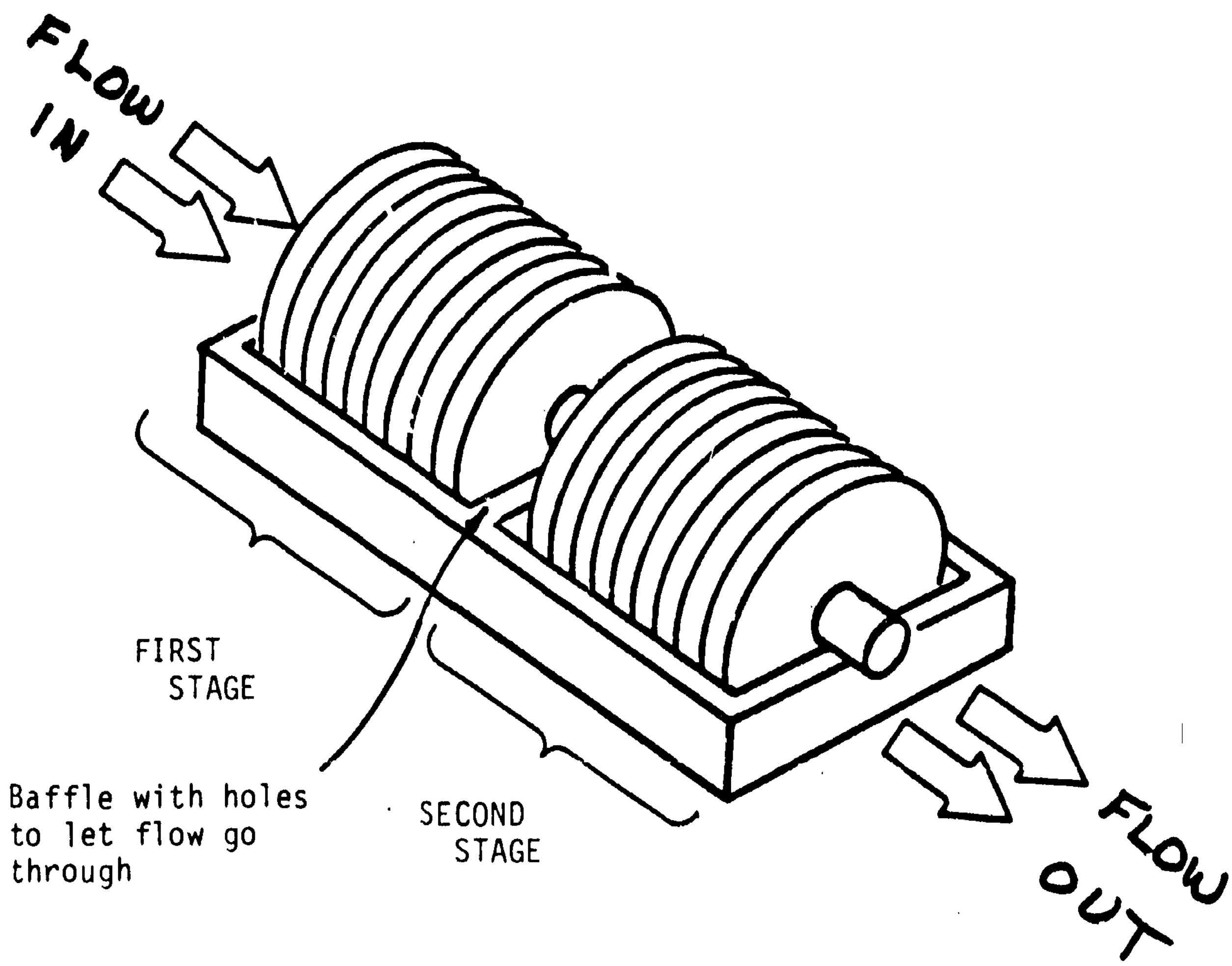
FIGURE 7



TWO PARALLEL
FOUR-STAGE TRAINS

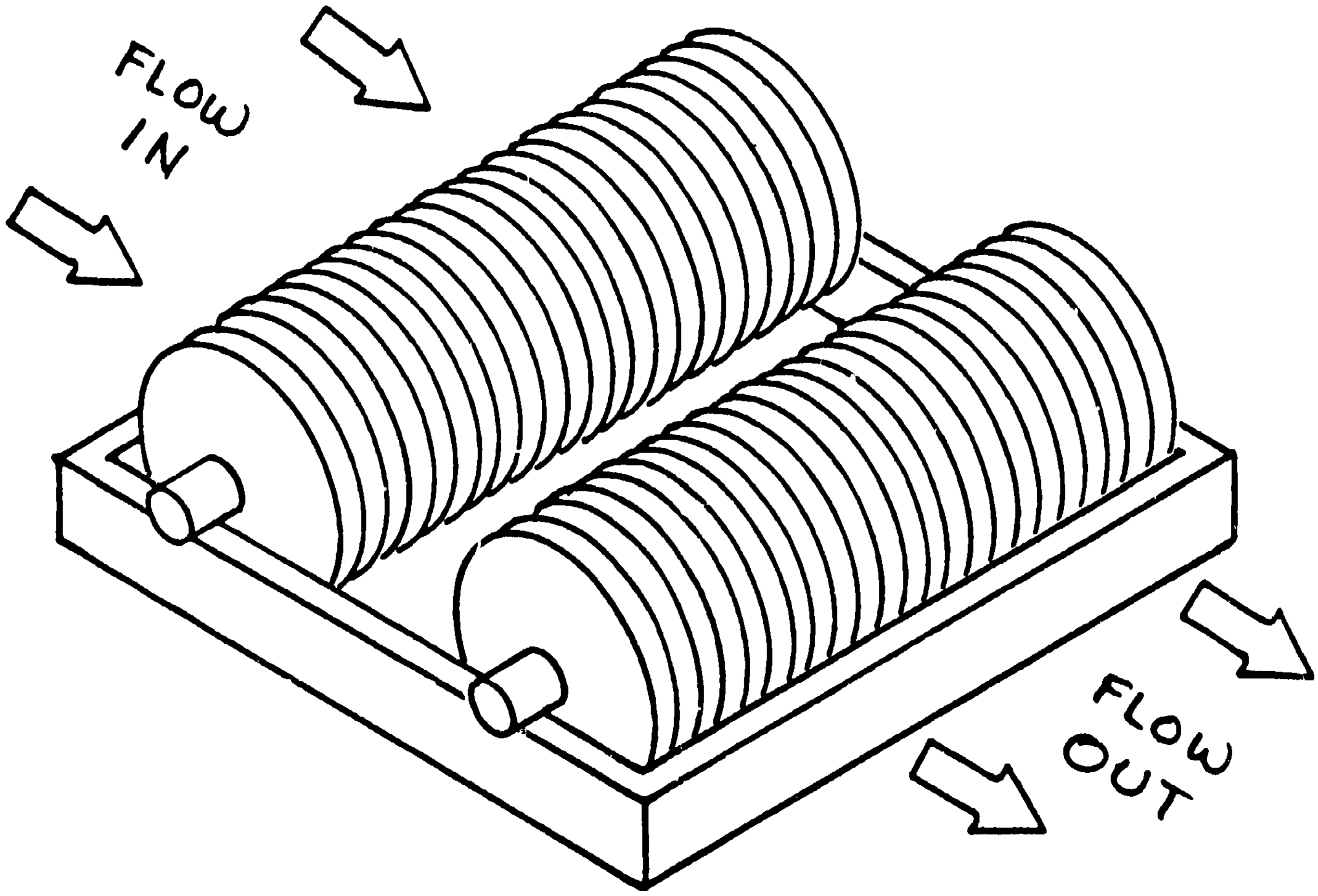
FIGURE 8

RBC-10



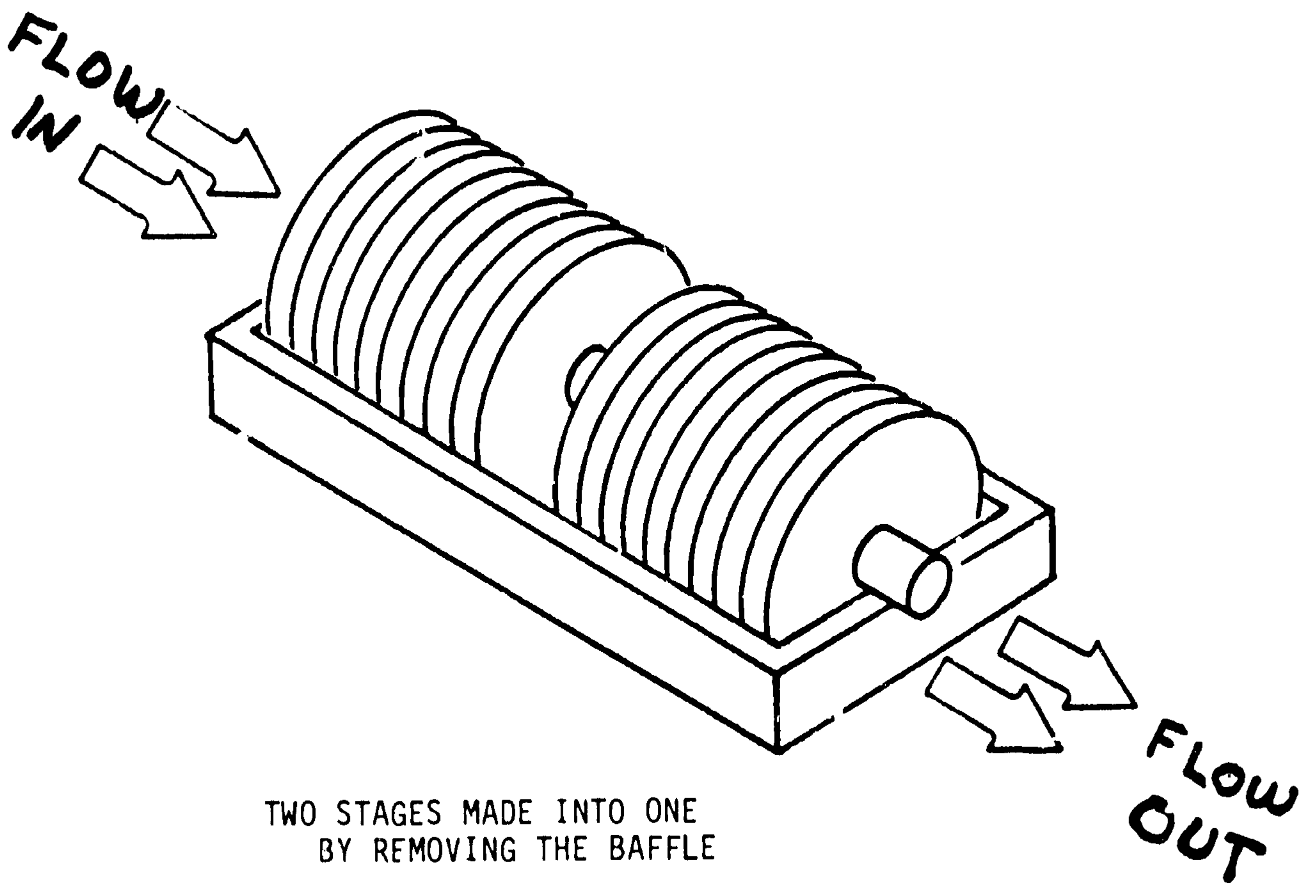
TWO STAGES ON ONE SHAFT

FIGURE 9



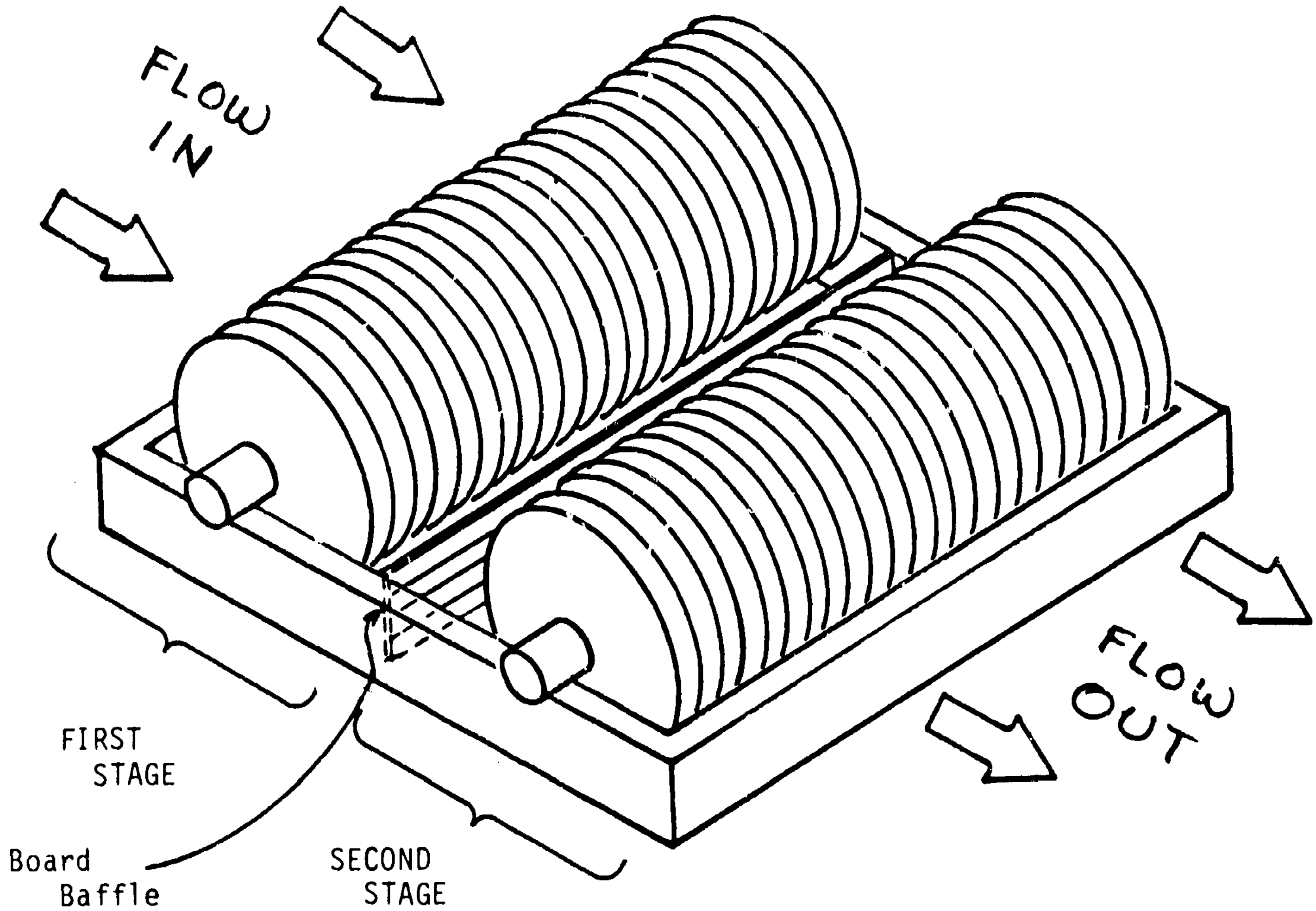
TWO SHAFTS IN ONE STAGE

FIGURE 10



TWO STAGES MADE INTO ONE
BY REMOVING THE BAFFLE

FIGURE 11



ONE STAGE MADE INTO TWO BY
PUTTING IN A BAFFLE

FIGURE 12

If enough flexibility is built into the system, you can use the gates and baffles to custom design a flow path for nearly every occasion. Figure 13 shows a flow path for treating a waste with an extremely high soluble BOD loading.

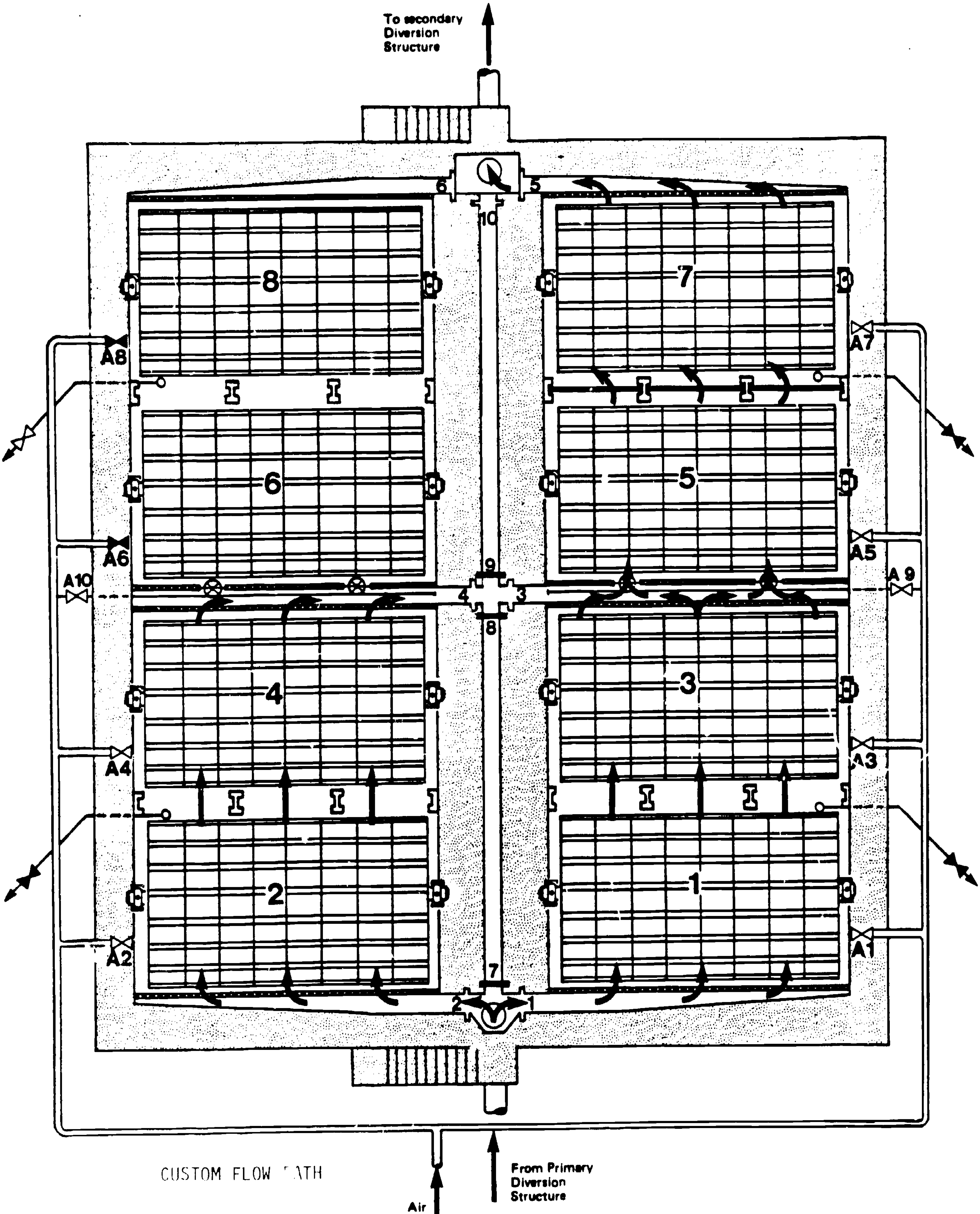
Two philosphies prevail on media design. One type of media uses spaces between segments to let water into the center area which then flushes in and out along the length of the shaft. See Figure 14.

The other type of media causes the water to be flushed in and out in a motion generally to and from the shaft. It has concentric grooves between each individual disc and does not have the spaces between segments. See Figure 15.

The biomass growing on the media is generally no more than a few hundredths of an inch thick. Healthy biomass is brown on the first stage and tends toward lighter brown, gold, or reddish in later stages. White or grey biomass is generally not healthy. Under the microscope the brown biomass is mostly free swimming ciliates, stalked ciliates, and rotifers. The lighter brown and reddish biomass has some higher worm forms. All biomass has some filaments - sphaerotilus. White and grey biomass has too many filaments. Staining techniques are usually required to identify them, but beggiatoa, thiothrix, and leptothrix are common.

Mechanical drive systems power the shaft from one end through either a triple reduction gear reducer or a combination of gear reducer and chain drive. The torque required to turn a 25-foot-long shaft from one end causes a high twisting effect in the shaft which has led to problems where a heavy biomass causes a large drag force.

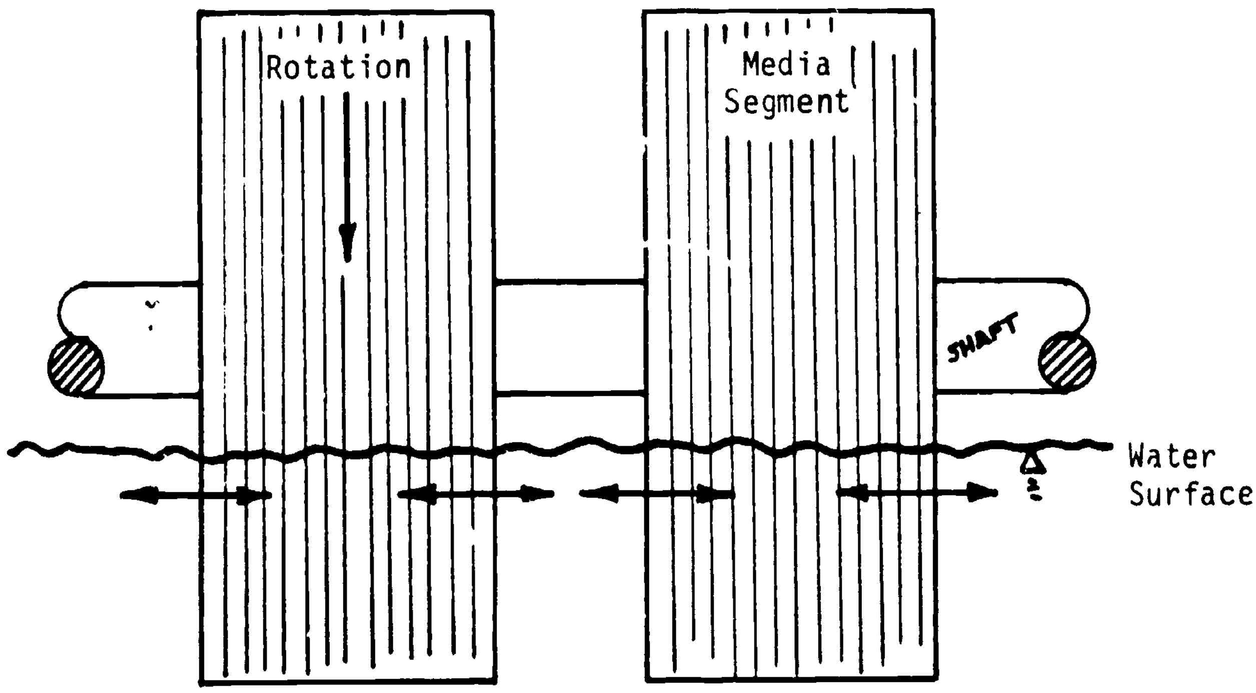
The shaft twisting problem has been eliminated in some systems by using an air drive system. The air drive system uses air cups mounted on the outside of the media to catch air from a submerged air header. The air cups buoy to the surface, each pulling its share of media with it.



CUSTOM FLOW PATH

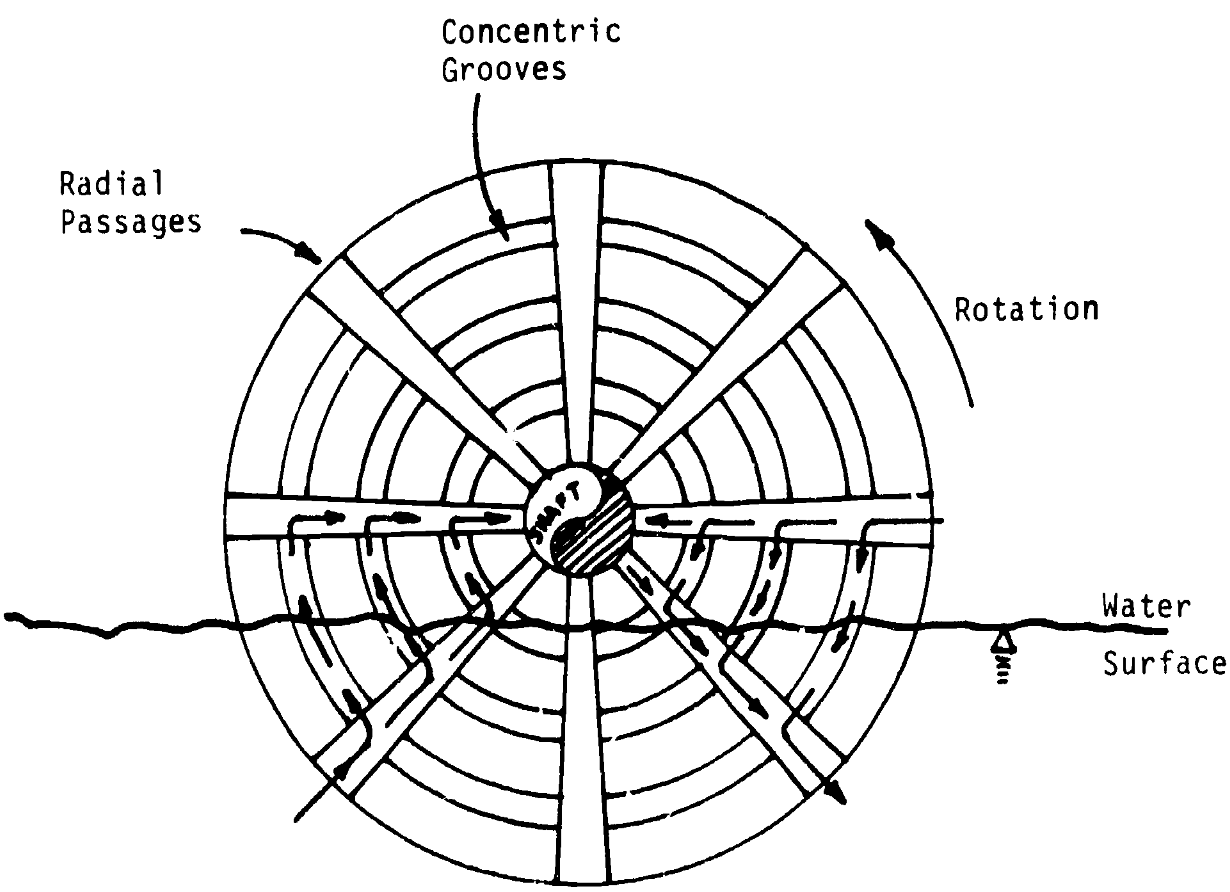
FIGURE 13

RBC-16



AXIAL FLOW

FIGURE 14



RADIAL FLOW
FIGURE 15

Two added benefits of using an air drive system are a continuous shearing of excess biomass leading to a lighter shaft and higher dissolved oxygen levels in the tank. These benefits have led to a limited number of auxiliary air headers being installed in tanks using a mechanical drive system.

CHARACTERISTICS OF BIOMASS

Biomass is a general term describing the growth on the RBC media. Normally, identifiable biological species are the only constituents in the biomass, but mineral deposits, grease deposits, and gelatinous growths can also be identified. Grease deposits are generally avoided if the wastewater treatment plant has primary clarifiers on line and all RBC manufacturers recommended this. Mineral deposits occur when the water supply is especially "hard," or industrial users are connected. Gelatinous growths can occur during startup and cause severe plugging problems. This apparently is not a common problem and seems to go away as mysteriously as it comes.

Biomass on stages being used for carbonaceous BOD removal is brown and uniformly thin. As BOD levels approach 15 milligrams per liter in a stage, the uniformity is replaced by a patchy appearance. Biomass on stages being used for nitrification ranges from light brown to gold to reddish. It is always patchy and often has large areas of bare-looking media.

Startup of new RBC shafts generally follows a common pattern. Almost immediately after clarified raw sewage is introduced to the tanks, a slimy feel occurs on the media. If the water temperature is warm, 18 to 20 degrees C., a noticeable growth starts occurring on all stages in 3 to 4 days. If the temperature is low, less than 15 degrees C., or if the sewage strength is very weak the growth takes longer to appear. The growth becomes thicker and is fairly uniform on all shafts just long enough to develop a false sense of security that all is proceeding nicely. It then starts sloughing off in great chunks. The sloughing is a completely normal and anticipated step in biomass development and is not a cause for alarm. The new growth is the real thing and develops the typical progression through the stages.

Once operating normally, the first stage remains brown and uniformly thin. The succeeding stages go in and out of patchiness and color changes as the soluble BOD goes up and down. A long period of light loading causes a large sloughing of starved biomass in later stages and the establishment of a predominantly nitrifying population. The return of higher BOD loadings re-establishes the carbonaceous bacteria on the shafts and pushes the nitrifiers to later shafts, or right off the end. The nitrifiers generally do not compete well with the carbonaceous bacteria if BOD levels are greater than 15 milligrams per liter.

MECHANICAL FEATURES

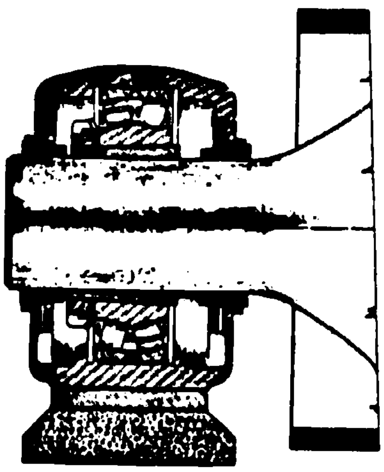
Bearings

Three types of bearings are used to support RBC shafts. Spherical roller bearings are most popular since they are reliable and tolerate deflection and misalignment better than other types. Figure 16 shows a spherical roller bearing. Sealed and non-sealed tapered roller bearings, or pillow block bearings as they are commonly called, are the other two types used. Figure 17 shows a cross-section of a non-sealed tapered roller bearing. The sealed tapered roller bearing is similar except it has continuous seals and a pressure relief plug on the bottom.

Every RBC shaft has at least one bearing designed to accommodate thermal expansion as the shaft heats and cools. Most shafts have one expansion bearing and one non-expansion bearing. As shown in Figure 17, the only difference is in how the cartridge rests in the bearing housing.

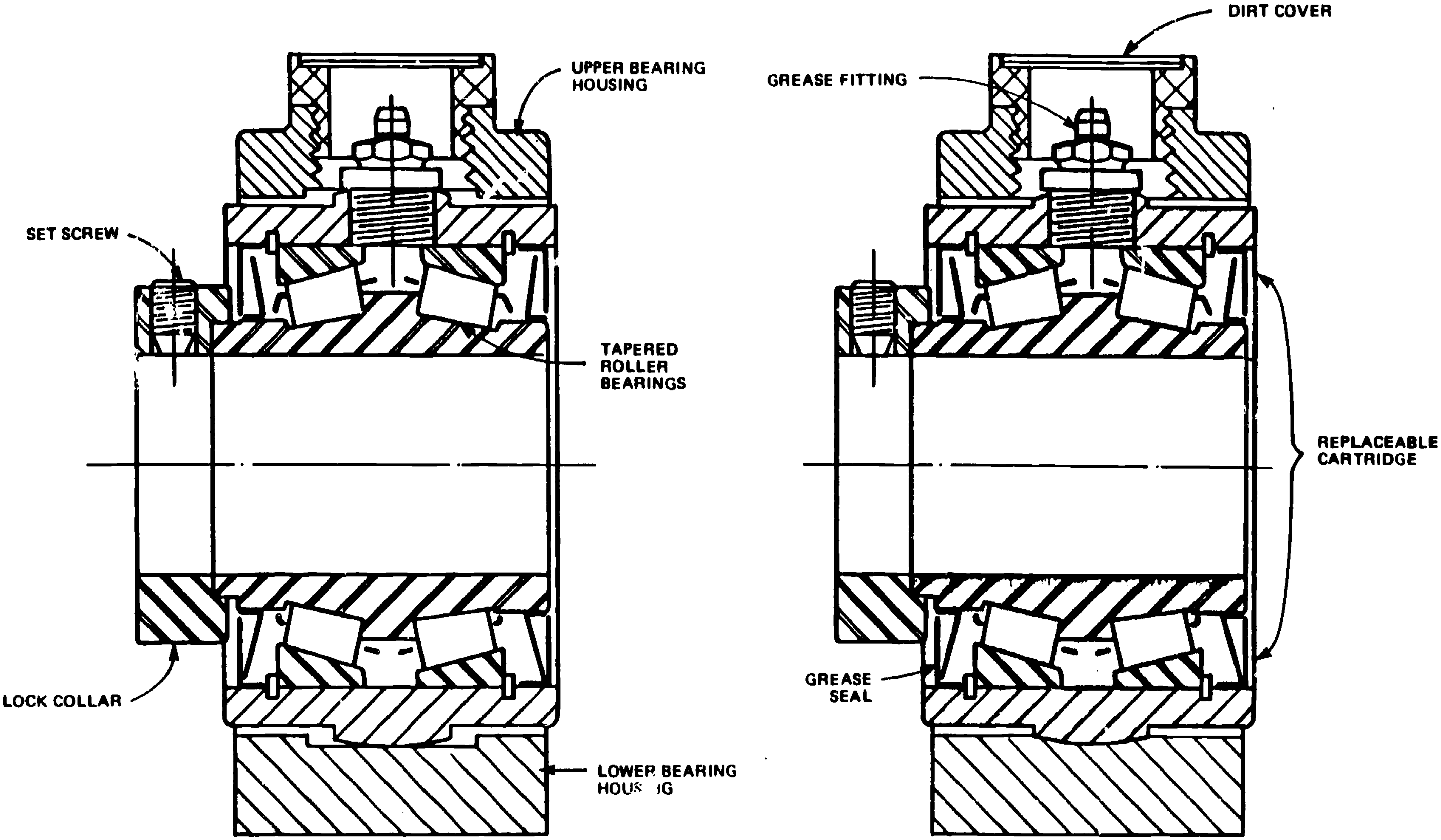
Mechanical Drive Systems

Mechanical drives fall into two main categories, chain drive and direct drive. All have other features in common including a motor, belt drive to the gear reducer and either double or triple gear reduction drive system. In general, double drive reducers are used on chain drive models and triple reducers are applied to direct drive models.



SPHERICAL ROLLER BEARING

FIGURE 16



EXPANSION

NON EXPANSION

BROWNING TAPERED ROLLER BEARINGS

FIGURE 17

The driving force of the motor and gear reducer must be able to start the media in motion when the disc is submerged and loaded with biological growth. The worst condition to bring the units into use occurs when the media has been submerged for several hours without rotating which may result during sustained power outages. This problem is discussed in a later lesson.

Examples of components in the mechanical drive system are shown in Figures 18 and 19. Figure 18 shows the arrangement of the motor, gear reducer, and chain drive. Figure 19 is an example of a triple drive reducer directly connected to the shaft.

Important features of the mechanical drive system for the operator to monitor are:

- Check belt tension; when more than one belt is used all have to have the same tension. During extreme overload, belt slippage will occur.

- Lubricate motor, gear reducer and bearings as called for by the manufacturer.

- Observe signs of shaft fatigue near the drive bearing end (this has been a historic weak point particularly in units installed prior to 1980).

The chain arrangement may be either a submerged or nonsubmerged application. Some operators have found it advantageous to apply a marine type grease to the chain to prolong its life,particularly in a submerged application.

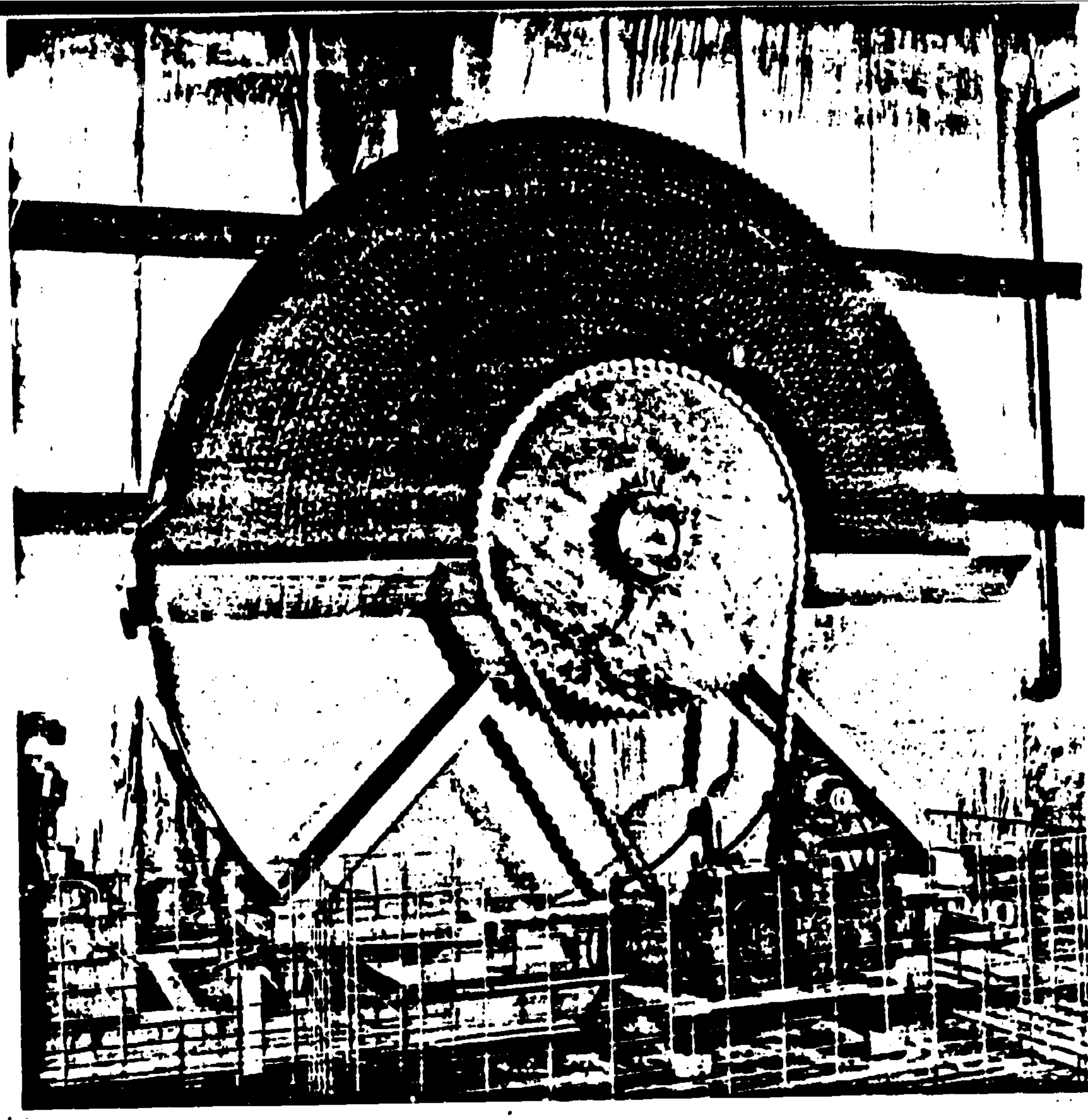


FIGURE 18 - Motor, Reducer and Chain
Drive Arrangement

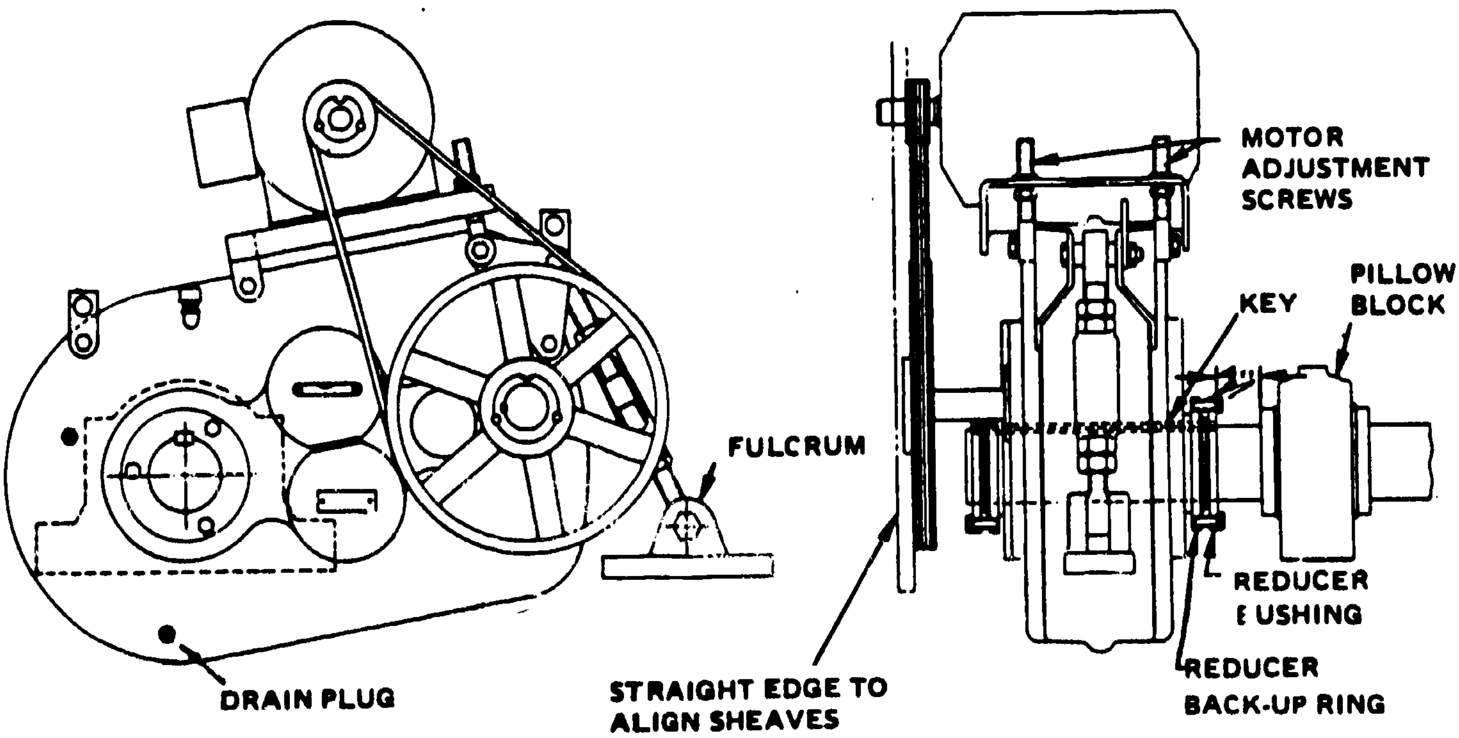


FIGURE 19 - Triple Reduction Gear Reducer
with Direct Drive

Air Drive Systems

As mentioned earlier, air drive systems have three major advantages over mechanical drive systems -- there is less torque applied to the shaft, the biomass is thinner, and the dissolved oxygen levels in the tank are higher. Obviously, there are disadvantages since only one major manufacturer has committed to manufacture the air drive option. The initial cost is higher since the blowers, air piping, and controls are more expensive than the mechanical drives they replace. The power cost is much higher primarily because the efficiency of the air drive is lower than the mechanical drive. The air drive system needs to be monitored and adjusted regularly to avoid shafts going out of balance since there is no positive means of speed control.

Air driven shafts are similar to mechanically driven shafts except polyethlene air cups are pinned to the outer periphery of the discs to trap air bubbles released from an air header mounted in the tank below the shaft. The air header has equally spaced diffusers to spread the air over the full length of the shaft. Each shaft has an air supply valve in its air header to regulate the amount of air and consequently the shaft speed. The air supply is furnished by either positive displacement or centrifugal blowers with centrifugal blowers being preferred. Centrifugal blower capacity is adjustable simply by throttling the blower suction valve. Positive displacement blowers must be capable of being operated at variable speed or be continuously vented to atmosphere through relief valves which is noisy and inefficient. Generally, the RBC blowers are used exclusively for RBC's and not manifolded to serve other on-site air requirements. Air pressure required for RBC's is low (2.7 psi) and is not enough for most other air requirements. Pressurizing the air to satisfy other air requirements and then depressurizing to the RBC's is noisy and extremely inefficient.

RBC air requirements are expressed in actual cubic feet per minute (acfm) for existing conditions. The blower suction and the ultimate discharge point at the RBC water surface are both in the same atmosphere and the need for reading pressure and temperature, and then using the gas laws is eliminated. For positive displacement blowers the acfm is directly proportional to blower speed and for centrifugal blowers the acfm is directly proportional to motor amps. Etching a second scale onto either of these two metering devices to read in acfm is accurate to within about five percent which is close enough for RBC operation.

RBC PROCESS CONTROL

DESIGN CONSIDERATIONS

RBC process control is usually very simple and is used as one of the major selling points for RBC's. Mechanical drive systems in small plants are often installed as simply ON/OFF type systems and there really are no process control decisions to be made. Larger mechanical drive plants sometimes have options available for how many stages can be on line and how many shafts can be put in each stage. Air drive plants always have process control decisions concerning shaft speed and may also have the options described above for larger mechanical drive plants.

When the design engineer selects the RBC process for a given installation, several items must be considered. Among these are:

- Flow Rates
- Organic and Solids Loading Levels
- Industrial Waste Influence
- Weather (heat, cold, extremely wet, etc.)

Each of the design considerations eventually become operation considerations when the plant goes on-line. Example design numbers for the RBC process are:

- Flow rates of 2.25-2.5 gpd/square feet
- Four pounds BOD/day/1,000 square feet
- 1.7 pounds BOD/day/1,000 square feet - total plant capacity
- 13 degrees C. (55 degrees F.) or above

Flow Rates

The operator may or may not have control over flow rates into the plant depending if the source is essentially domestic and arrives through a gravity collection system or if there are a number of pump stations which cause gross fluctuations due to pumps cycling on and off. The tightness of the system is also a concern particularly if high amounts of infiltration are received.

Any biological system functions best if the flows are nearly constant and any control the operator can exercise to make this happen will improve plant efficiency. Sometimes this can be done by regulating pump station operation to smooth out surges caused by constant speed pumps cycling on and off. Variable speed controls may be installed if this is the only measure needed to bring the plant into compliance with water quality requirements. Flow equalization may also be accomplished by using standby primary clarifier capacity or other means to absorb high flows.

Problems arising from fluctuating flows include physical scouring of biological growth off the media, reduced detention time which prevents bacteria from absorbing soluble BOD and reduction of temperature which reduces overall removal efficiency. Sometimes when extremely wide variations between daytime and nighttime flows are experienced the plant efficiency can be improved by recycling RBC effluent back to the head of the plant to provide some food during night hours.

Organic and Solids Loads

The number of discs are normally selected on the basis of the anticipated soluble BOD load and the expected temperature extremes. The desired quality of the effluent determines how many stages will be required and what flow configuration will be used. The innovative operator will monitor the waste strength and set up the most efficient flow pattern to obtain the effluent quality required. Later portions of this lesson will discuss how and why to adjust flow patterns.

If the plant has different densities of the media on the shafts the decision to use high or low density was made based on what the goals for BOD removal were and the number of stages influenced nitrification and overall BOD removal.

Generally provisions were made to vary the amount of shafts for first stage use so that increased BOD loads could be accommodated. If the plant is designed for approximately four pounds BOD/day/1,000 square feet and higher loads are experienced the operator must make process changes to prevent overloading. If provisions are made to spread the load over several shafts in the first stage this is done by simply directing RBC influent to additional units. If no provision was made, some operators have physically increased the capacity in the first stage by removing existing walls or baffles between the stages.

In other cases, mechanical drive units have gained efficiency by the addition of air headers under the disc. This modification is made easier if the plant already uses aerobic digestion for solids stabilization and the source of air is readily available. This method has also been used to keep solids in suspension for plants that have an inefficient primary clarifier.

Industrial Loading

The RBC process has been used in a number of industrial applications and when design for the proper types and amounts of industrial waste can be made to function very efficiently. The difficulties come when industrial wastes are introduced to a domestic system not specifically designed for it.

New and unplanned for industrial loads are best handled by enforcing an industrial waste ordinance to require the industry that is upsetting the plant to modify their waste stream to make it compatible and treatable. Shock loads or toxic loads are the two most commonly encountered problems and if all else fails can be marginally handled by making some process changes.

High strength waste that are compatible with the biomass should be equalized at the industry or if provisions are made for some type of equaliziation on site the impact should be spread over the longest possible time periods. Increasing the number of shafts on the first stage to keep average BOD loads below the design levels is another control technique.

Toxic waste that kill the biomass must be controlled at the source. If occasionally accidental spills are received an effort must be made to set up a warning system by having industry warn the plant operator of the loss of toxic material to the system and estimate the amount. If more than one primary clarifier is available, flow can be diverted into the extra clarifier and held to be either pumped out and disposed of in an approved manner or fed through the system at a very slow rate to prevent damage to the biomass. An example is the receipt of waste containing metals such as copper or chromium. In high concentrations, this will kill the bacteria but at lower concentrations it can pass through with minimal harm.

Weather and Environmental Influences

The designer must take into consideration the potential for hydraulic overloads due to infiltration and more importantly consider the temperature fluctuations. Research has shown that the RBC process efficiency drops off very rapidly below 13 degrees C. (55 degrees F.). As winter temperatures begin to drop the influent water temperature below this level more shafts will be required to achieve the same efficiency as at higher temperatures. For air driven units an increased amount of air will be needed for low temperature operation.

Summary

Although the operator cannot do much about changing the overall design of the plant once it is built he should be aware of why the plant was built and sized as it was, but he should not overlook the possibility of making minor changes to increase efficiency using the same principals the design engineer used in his initial approach.

INTERACTION OF UNIT PROCESSES

The RBC process is dependent to a great extent on other parts of the plant to allow the biological process to work efficiently. The function of other unit processes must be used correctly to accomplish process goals. These unit processes are preliminary treatment, primary treatment, and any other process that changes the influent characteristics to the RBC such as return streams from anaerobic digestion, etc.

Preliminary Treatment

Efficient grit removal and screening or communition is essential to prevent solids buildup under or on the discs. Some operators have experienced severe buildup of grit in the basin under the disc. If anaerobic conditions are allowed to develop, certain bacteria and fungi may begin to grow on the disc surfaces causing reduced efficiency and odors.

The efficiency of both grit and screening or communition should be checked at least monthly. This is best done indirectly by measuring or sampling under the discs at several locations. If more than 2-3 inches of accumulation is found it should be cleaned out. Some operators have found small diaphragm pumps with a noncollapsable suction hose useful. The material is "vacuumed" out and disposed of with the grit. Small accumulations may be flushed out with high pressure water or compressed air and handled in the secondary sludge. Care must be taken not to force high pressure water into the disc driving biological growth into the interior of the media. If these accumulations become too frequent a chore, the efficiency of preliminary treatment units should be improved either by the addition of more units or improving the operation control.

Primary Clarifier

The operation of the primary clarifier determines the loading on the RBC units and must be controlled to prevent needless recycle of solids in the clarifier effluent. This may be a particular problem if secondary solids are returned to the primary clarifier and solids handling units become overloaded. As more solids pass to the RBC's the same problem as cited for the inefficient preliminary units can result. Keeping the solids pumped out of the tank will prevent bulking of solids particularly in hot weather.

Return Streams

In plants that have any process that allows side streams to return to the headworks at any location upstream of the RBC the potential loading effects have to be considered. Many times the aerobic digester supernatant, anaerobic digester supernatant or return streams from sludge drying beds and lagoons are brought back to a point ahead of the RBC units. Anaerobic digester supernatant can contribute very high BOD's as well as ammonia to RBC influent. Sometimes sampling points are located such that they do not pick up these loads and overloads occur without the operator being aware of it.

It is important to monitor return stream loads for BOD, suspended solids, ammonia and any other parameter that might reduce the RBC efficiency. Pretreatment by aeration, additional settling or other measures may be necessary to prevent plant upset.

Secondary Clarifier

If sloughing of the discs occur due to toxic loads, temperature change or hydraulic flushing the clarifier will receive high solids loads which in turn will influence processes handling the solids. The operator must control this operation to prevent getting into a merry-go-round effect which causes more loading on the RBC which in turn causes more solids load to the secondary clarifier. Close monitoring of the amount of solids pumped and expressing this in pounds per day will help the operator spot and correct this problem.

PROCESS MONITORING AND TESTING

Visual Observation of the Biomass

A daily inspection of the shafts by a trained operator is the most important element of process monitoring. The daily inspection is usually made in conjunction with the daily operation and maintenance inspection described in the next section.

First stage biomass is usually the most critical. Healthy first stage biomass is a uniform brown color and uniformly distributed in a thin even layer. A heavy shaggy biomass in the fist stage represents a heavy organic load on the plant. Unanticipated high strength industrial wastes are often found to be the cause of an overloaded first stage. In-plant return streams, such as digester supernatant, are also frequent causes of an overloaded first stage.

If the first stage biomass is heavy, shiney, and developing white splotches, beggiatoa is growing. Beggiatoa develops when sulfides are present. The sulfides may result from extreme overload resulting in zero dissolved oxygen levels in the first stage tank, from septic wastes entering the treatment plant, from industrial contributors of hydrogen sulfide, or from anaerobic deposits in the bottom of the RBC tank. The larger RBC installations which use several shafts in a flat bottom tank are especially susceptible to anaerobic deposits. A somewhat successful means of removing the anaerobic deposits is to open the tank drain valves on a weekly schedule and flush out the deposits. High sulfide levels in plant influent can be lessened by preaeration, ozonation, or hydrogen peroxide addition at the plant influent.

Stages following the first can come in many colors and in several conditions of biomass. Mostly, they will be in shades of brown and progressively more patchy as you move away from the first stage. The brown color is characteristic of biomass in which the carbonaceous bacteria predominate. When the wastewater temperature is below about 15 degrees C., the brown color will appear on all stages, but at temperatures above 15 degrees C. the brown gives way to tans and golds.

Light browns, tans, and golden shades are predominately nitrifying populations. The nitrifiers require temperatures above 15 degrees C., BOD concentrations less than 15 milligrams per liter, and neutral pH. The nitrifiers can help or hurt RBC operation. Ammonium-nitrogen in the wastewater is converted to nitrate-nitrogen by the nitrifiers (which is good from a water quality view point) if sufficient oxygen and alkalinity are available. Each part of ammonium-nitrogen converted to nitrate-nitrogen requires seven parts of alkalinity, and if the wastewater is low in alkalinity the nitrification can cause pH to drop as the alkalinity is consumed. Once the pH drops below about six, the nitrifiers die and the pH returns to neutral as alkalinity returns.

If the nitrifiers are established on the later RBC stages and there is not enough population for complete nitrification of all ammonium-nitrogen in the wastewater, then the plant final BOD's can be high due to the oxygen demand exerted from the nitrifiers in the BOD bottle. Since wastewater treatment plant performance is based on carbonaceous BOD and not nitrogenous BOD, the final BOD should be performed for carbonaceous BOD only. The 15th edition of Standard Methods has recognized the conflict and recommends that final BOD's be performed using a nitrification inhibitor which kills the nitrifying bacteria while not harming the carbonaceous bacteria.

Reddish colored biomass is not too common, but tends to occur where there are so many stages in an RBC train that nitrification is essentially complete. The reddish tint is caused by higher worm forms starting to predominate, specifically the blood worms which contribute to the red color.

Testing requirements for RBC's are similar to those for trickling filters. Common tests include influent and effluent BOD's and suspended solids analyses, dissolved oxygen, pH, and temperature. More sophisticated tests used where process control is based on test results include ammonium-nitrogen, nitrate-nitrogen, alkalinity, and soluble BOD.

Microscopic examination of the biomass is interesting and can be used to learn a great deal about how individual RBC trains are operating. Presently there are no guidelines for using microscopic examination as a process control tool, however, some plants are attempting to develop a correlation between effluent BOD's and the predominance of various species in the process.

PROCESS CONTROL FOR STEADY STATE OPERATION

Mechanical Drive Systems

Steady state operation includes the monitoring and testing requirements given above. Most of the day-to-day operation consists of performing the maintenance requirements.

The shaft bearings should be inspected daily. The bearings should be cool and absolutely rigid to the touch. They should be quiet enough to not be heard above the splashing. Periodically, a screwdriver or metal rod should be put to the bearing housing and the other end to the thumb in the ear. After hearing one normal internal bearing sound, a bad bearing can be noticed immediately by an uneven rumble or periodic thump. Depending upon manufacturer, the bearings need to be lubricated anywhere from twice per week to once every three months. RBC manufacturers' recommendations for frequency of lubrication and type of lubricant should be followed carefully.

The drive motors should be checked daily. these motors are generally 5 to 7-1/2 horsephower, 3-phase, AC induction motors and should run cool enough to allow putting the hand on them indefinately without pain (less than 140 degrees F.). The motors are probably the most reliable component in the drive train and generally have few problems. Motors in this size range may require a semi-annual or annual bearing lubrication, or may have sealed no-lube bearings. Read and follow the motor manufacturer recommendations carefully before lubricating any motor. If motor amp readings are recorded, they should be taken and logged at least semi-annually.

The speed reducers should be checked daily for excess noise or obvious oil leaks. If the unit has an external site glass it should be checked daily. As with the bearings, a periodic check with a screwdriver or metal rod will reveal much about the internals to a practiced ear. The speed reducer oil needs to be changed from semi-annually to annually depending upon manufacturer. Follow the speed reducer manufacturer's recommendations carefully concerning frequency of oil change and type of oil.

The drive chain and sprocket should be observed daily. Worn sprockets or stretched chains can be observed before damage occurs by watching the teeth and chain as they mesh. Submerged and dry chains have different lubrication requirements and the RBC manufacturer recommendations should be followed.

The belt drive should be noted daily. Belt squeal is usually the first indication that something is wrong. The smell of warm rubber is the second. The major point to remember about the belts is that they come as a set. If one belt is replaced, the whole set must be replaced with identical belts by the same manufacturer. Every three to six months the belt tension should be checked according to conventional belt tension checking techniques.

Air Drive Systems

Steady state operation for air drive systems involves more careful monitoring and more adjustment than mechanical drive systems operation. In addition to the monitoring and testing requirements given in the previous section, shaft and blower maintenance must be performed, shaft speeds and balance must be maintained, and biomass thickness needs to be controlled.

Shaft speeds need to be checked daily by timing the number of seconds to complete a full revolution. The actual speeds are recorded and compared to recommended "speed profiles" furnished by the manufacturer. If shaft speed leaves the recommended range, the air supply valves need to be adjusted to return all the shafts to the recommended speed range. The procedure for doing so is based on always having the air supply valve to the slowest shaft fully open and throttling the faster shafts. Once the shaft speeds are balanced with respect to each other, the whole system is slowed down or speeded up by adjusting the blower suction valve for centrifugal blowers, or the blower speed for positive displacement blowers.

Once or twice a week each shaft needs to be timed for quarter revolutions. The number of seconds required for each one quarter turn must be the same for each quadrant or the shaft is going out of balance. Once a shaft starts to go out of balance, it only gets worse since the heavy side tends to stay on the bottom longer which gives it more time in contact with its food supply which causes the biomass on that side to become even heavier. If a shaft going out of balance is detected early, it can be stripped of the excess biomass by air purging (described below), but if it is badly out of balance it usually requires shutting down that shaft and draining the tank to let the biomass die, or else chemically stripping the biomass.

Once a month, or more frequently, all the operating shafts are air purged by putting extra blower capacity on line to furnish up to 150 percent of the normal air volume. The purging process strips off excess biomass to keep the layer thin and helps to minimize the frequency with which the shafts become unbalanced.

Once a day the RBC air supply pressure should be monitored at the blower discharge. A very accurate low range pressure gauge or manometer should be used. For every installation there is a definite discharge pressure which represents the sum of the height of the water surface above the air header and a piping head loss. Montoring the pressure daily allows discovering clogged diffusers, flooded diffusers (the older installations do not have diffusers on the bottom for blowing out flooded headers), or throttled air supply valves to all shafts. The proper discharge pressure together with the proper shaft speeds virtually assures a problem-free air supply system.

Once a day the tank should be inspected all the way around the shafts. Random air cups break off occasionally and can become jammed between the tank walls and the rotating shaft. Several air cups can be missing without adversely affecting operation, but a free cup becoming jammed can tear up several others.

Blowers used with air drive RBC systems are supplied by several manufacturers. Each manufacturer has different maintenance requirements and schedules for his equipment and the recommendations should be followed. In general, centrifugal blowers have shaft bearings, flexible couplings, and motor bearings to lubricate. Overloaded centrifugal blowers trip their motor overload relays and underloaded blowers go into surge. Centrifugal blowers are most easily monitored by reading, recording, and comparing motor amps on a daily basis. Blower load is adjusted by throttling the unit suction valve.

Positive displacement blowers generally have shaft bearings and motor bearings to lubricate. Drive belts and variable speed units need periodic attention depending on type. Blower load is controlled by varying blower speed. If the blower speed is too high, the discharge piping overpressurizes and lifts the system relief valve.

MAKING PROCESS CONTROL CHANGES

Reivew of Control Options

The operator has several tools available to him to change the process and by understanding this he can improve effluent quality even under difficult circumstances. Several definitions were given in the previous lesson outlining the principal equipment arrangements common to RBC's. These were:

- Disc - media which turns in the water and supports the biomass.
- Train - series of shafts arranged for water to flow from one to another.
- Baffle - dividing wall between shafts separating them into stages. These may be movable or fixed.

- Stage - segment of the tank or basin containing the shaft.
- Shaft - rotating portion of the RBC made up of the disc or media and structural members that support the media.

These are the components that can be arranged within certain limits to change the process and accomplish effluent goals. Two other options the designer has in selecting RBC's are between air drive and mechanical drive. Further choices are between variable speed mechanical or fixed speed.

The range of flexibility will be from the plant that has a mechanical drive with fixed speed and a single stage arrangement to the multiple stage plant with removable baffles, getting arrangement to direct flow to different units and variable shaft drive capabilities (either by mechanical or air driven). The following discussion assumes some flexibility but may not include all of the latter options.

<u>Set Up For Maximum BOD Removal Without Nitrification</u>

The operator must know what the goals are for his plant before he exercises any of the control options open to him. These are generally dictated by the NPDES permit, O&M Manual, water quality standards or special agreements with local or state regulatory agencies.

If the goal is to obtain the maximum BOD removal without moving into nitrification it is necessary to have the maximum number of shafts operable in the first stage. One of the visual indicators for overload in the first stage is the presence of <u>Beggiatoa</u>, a sulphur bacteria that begins to appear when BOD is high or anaerobic conditions exist in a sludge layer below the disc. Another indicator is the low DO reading and this coupled with the presence of Beggiatoa is an indication that the normal organisms cannot compete.

The indications of nitrification occuring have been described previously. Through proper operation the BOD level at the effluent stage can be kept at about 20 milligrams per liter without nitrification occuring.

Set Up To Maximize BOD Removal During High Loading

As loads increase due to seasonal industrial contributions, recreational waste reception or other periodic occurrances it may be necessary to change the flow path to accommodate greater than average influent BOD loads. The same overall approach is used as that described for preventing nitrification which is to maximize first stage capacity in order to increase the amount of BOD removal while maintaining the desired effluent values. The goal will be to satisfy the BOD without developing nitrifiers in later stages.

Setting Up To Encourage Nitrification

The previous control steps have described methods to discourage nitification. If nitrification is desired, the general trend is to maximize the number of stages in series in a train. The conditions that favor nitrification were described earlier. Generally, BOD entering the stage that will support the maximum number of nitrifying bacteria is at or below 15 milligrams per liter.

Nitrification activity will remove alkalinity from the water and result in reduced pH if buffering capacity is reduced. If facilities are available to measure ammonia nitrogen and alkalinity, these tools will be helpful in controlling the process. Optimum nitification takes place between pH 7 and 8.4. If values drop to 6.5 or below, it may be necessary to add sodium bicarbonate to bring the levels back to the optimum range. The nitrification process consumes approximately seven pounds of alkalinity for every pound of ammonia nitrogen converted to nitrate. Therefore if the amount of ammonia nitrogen is known then the amount of alkalinity required can be calculated.

SUMMARY

Operation of the RBC system is more than "just turning it on and letting it run itself." The operator has a number of options even in plants with limited flexibility if he is willing to use his ingenuity.

Certain visual indicators such as the appearance of different colors of biomass, presence of odors and amounts of solids in the effluent of clarifiers and RBC overflow points give an indication of how the process is working. These have been described in the lesson, however, they have to be related to the individual plant before they have true significance to the operator. They are valuable and should not be overlooked or discounted.

Additionally, certain lab tests are also described to tell whether the first stage is overloaded, whether nitrification might be expected in later stages, whether nitrification is occuring and reducing pH, how much DO is present, etc. Test results should be used to make process control decisions, not simply to satisfy some regulatory reauirement. Use of this information has been described.

Maintenance must be performed routinely and preventive steps taken to keep the process healthy. Lubrication of bearings, maintenance of other moving parts such as shafts, belts, chains and media are all part of standard operation duties. The importance of this has been stressed above.

Finally, the RBC units are dependent on the correct functioning of the other processes. When all the parts of the process reviewed as tools needed to produce the end products, namely disposable solids and acceptable effluent the operator can be proud of the job he was doing.

ROTATING BIOLOGICAL CONTACTORS

(RBC's)

References

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2. Wastewater Engineering, Metcalf & Eddy, Inc., Second Edition, McGraw-Hill, pages 452-453.

3. MOP/II: Operation of Wastewater Treatment Plants, Water Pollution Control Federation, pages 105-115.

4. Unit Operations and Processes in Environmental Engineering, Tom D. Reynolds, 1982, Wadsworth, Inc., pages 382-383.

ROTATING BIOLOGICAL CONTACTORS

Worksheet 1 - Concepts and Components

1. The wastewater treatment process in which a shaft containing synthetic media is rotated in a tank filled with process water is called __________ __________ __________.

2. The rotating drum of the RBC unit that is made up of the media from end bearing to end bearing is called the __________.

3. A series of drums lined up in a row is called a __________.

4. The two basic arrangements for liquid to flow through an RBC plant is __________ and __________.

5. The tank or basin which is said to be the hydraulic point of no return is called the __________.

6. Healthy biomass is __________ colored on the first stage and tends toward ____________________ in later stages.

7. The two types of drum drive systems are:

   ____

   ____

8. When excess growth on an RBC drum falls off the media the process is called __________.

9. If the surface of the RBC media has a black color and there are strong odors then __________ conditions have developed.

ROTATING BIOLOGICAL CONTACTORS

Worksheet 2 - Process Control

1. Design flow rates for an RBC should fall in the _______ to _______ gpd/square foot range.

2. The normal range of BOD removal for a well operated RBC system is _____ to _______ percent.

3. Heavy, shiny, white patches of growth on the first stage biomass is a growth of ____________ bacteria developing when sulfides are present.

4. The recommended set up for maximizing BOD removal and/or dealing with high organic loads would be to maximize the number of __________ in the first stage.

5. To set up to encourage nitrification maximize the number of ________ in a train.

6. Give two advantages of the mechanical shaft drive system:

____

____

____

7. Give two disadvantages of the air drive system:

____

____

____

8. Calculate the hydraulic loading on an RBC system that has a total surface area of 600,000 sq ft and has a flow of 2 MGD.

9. Calculate the organic loading for an RBC system that is 750,000 sq ft and the BOD applied per day is 1800 lbs BOD/day.

10. Calculate the organic loading for an RBC system that has an influent BOD of 100 mg/l, a flow of 1.75 MGD, and a surface area of 400,000 sq ft.